ORDER

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FIBER OPTIC TRANSMISSION SYSTEMS AND EQUIPMENT HANDBOOK

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Initiated By: ASE-220

FOREWORD

Fiber optic technology has been evolving for 25 years. It has proven to be an effective transmission means where high reliability, very low bit error ratio, high communication security, wide bandwidth, high system capacity, low signal attenuation, and/or flexibility of use are required, or where cable conduit space is limited. Fiber optic equipment has been installed in commercial and military applications ranging from inside a computer and computer room to local and wide area networks to undersea cable connections.

The Federal Aviation Administration (FAA) has already installed fiber optic transmission equipment in areas around some airports, as well as inside some facilities; the agency should continue to consider fiber optic transmission systems an effective solution for many existing and future administrative and operational transmission requirements. This handbook provides FAA project personnel with guidance information for planning and implementing fiber optic transmission systems and equipment. Note that maintenance and inspection aspects of fiber optic transmission systems and equipment are thoroughly discussed in Order 6650.10, Maintenance of Fiber Optic Communications Equipment and are not addressed in this handbook.

This document contains the following sections:

- Basic fiber optic technology information;
- Selection criteria for transmission system;
- Potential FAA fiber optic communication requirements;
- Characteristics of fiber optic networks;
- Characteristics of fiber optic cables;
- Characteristics of fiber optic equipment;
- Use of FAA-STD-049 (FAA Standard for Fiber Optic Telecommunications Systems and Equipment) in the acquisition process;
- Pertinent communication and fiber optic standards and protocols.

This handbook will be updated periodically.

Robert f Wu

for Jack Lowenstein (Acting Director)
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CHAPTER 1. GENERAL

1-1. PURPOSE

The purpose of this handbook is to provide FAA program managers and network designers with information that may be used to plan and implement fiber optic transmission systems. To prepare acquisition documents, e.g., Requests for Information (RFIs) and Requests for Proposals (RFPs), this document should be used in conjunction with (a) FAA-STD-049, NAS Standard for Fiber Optic Telecommunication Systems and Equipment and (b) Order 1830., Fiber Optic Transmission Systems and Equipment Policy. Instructions for tailoring FAA-STD-049 for acquisition documents are provided in this document.

1-2. DISTRIBUTION

This order is distributed to the director level in Washington, to the division level in the Office of Air Traffic Plans and Requirements Service, the Office of Air Traffic Systems Management, the Life Cycle Management Service, the Program Director for MLS, Surveillance, Communications, Weather and Flight Service Systems, the Research and Development Service, the NAS System Engineering Service, the Facility System Engineering Service, and to branch level in the NAS Operations Program Directorate and the NAS Transition and Implementation Service; to division level at the FAA Logistics Center at the Mike Monroney Aeronautical Center and the Engineering, Integration and Operational Evaluation Service; to division level in the Office of Research and Technology Application, the Engineering, Test and Evaluation Service, and the Engineering, Research and Development Service at the FAA Technical Center; to branch level in the regional Airway Facilities divisions; and to the Airway Facilities sectors, sector field offices, sector field office units, and sector field units with a standard distribution.

1-3. SCOPE

This handbook provides (1) a brief tutorial on fiber optic technology, (2) selection criteria for various transmission media, (3) requirements for planning fiber optic networks, (4) a discussion of fiber optic networks and components, including transmitters and receivers, as well as optical fiber cable and (5) requirements for implementing fiber optic systems. Non-developmental Items/Commercial Off-the-shelf (NDI/COTS) equipment are required for FAA acquisitions, unless the benefit(s) of development can be demonstrated. The equipment described in this document is NDI/COTS.

Maintenance and inspection aspects of fiber optic transmission systems and equipment are thoroughly discussed in Order 6650.10, Maintenance of Fiber Optic Communications Equipment and are not addressed in this handbook.

1-4. APPLICABILITY

This handbook applies to all operational and administrative agency programs that have communication requirements for which fiber optics equipment has been selected, or is being considered, as the transmission means. Refer to section 4-2 for some potential FAA fiber optics applications.

CHAPTER 2. APPLICABLE DOCUMENTS

2-1. GOVERNMENT DOCUMENTS

The following documents provide detailed information on a number of subjects discussed or referenced in this order. In the event of conflict between the requirements of this order and the requirements of the documents referenced herein, this order shall have precedence.

STANDARDS

a. FAA-STD-049, FAA Standard for Fiber Optic Telecommunication Systems and Equipment, February 1994

b. Federal Standard 1037C, Telecommunications: Glossary of Telecommunication Terms

OTHER PUBLICATIONS

a. Logistics Support/Maintenance Management Plan (LS/MMP) for the Fiber Optics Transmission Systems (FOTS) for the New Denver International Airport (DIA), September 8, 1993

b. Order 1830., Fiber Optic Transmission Systems and Equipment Policy, Draft, Dec. 1994

c. Order 6650.8, Airport Fiber Optic Design Guidelines, August 14, 1989

d. Order 6650.10, Maintenance of Fiber-Optic Communications Equipment, August 26, 1993

e. DTS54-NWM-DVX-002b, New Denver Airport Power/Communications Design Study, Volume II, Airport Communications Configuration Study, November 27, 1989

f. FAA-E-2809, Manufacturing Specifications for Interface Modules and Boards, Fiber Optic Communications, Airport Facility

g. FAA-E-2810, T-Carrier with Drop and Insert, Fiber Optic

2-2. NON-GOVERNMENT DOCUMENTS

The following documents provide detailed information on a number of subjects discussed or referenced in this order. In the event of conflict between the requirements of this order and the requirements of the documents referenced herein, this order shall have precedence.

STANDARDS

a. ANSI X3T9.5, Fiber Distributed Data Interface Standard

b. ANSI T1.105, Telecommunications -- Digital Hierarchy -- Optical Interface Rates and Formats Specifications (SONET) (FDDI and STS Path Signal Level) (ECSA); Supplement T1.105A

c. ANSI X3.139, Information Systems -- Fiber Distributed Data Interface (FDDI) -- Token Ring Medium Access Control (MAC)

d. ANSI X3.148, Information Systems -- Fiber Distributed Data Interface (FDDI) -- Token Ring Physical Layer Protocol (PHY)

e. ANSI X3.166, Information Systems -- Fiber distributed Data Interface (FDDI) -- Token Ring Physical Layer Medium Dependent (PMD)

f. ANSI X3T9.5, Fiber Distributed Data Interface Standard

g. ANSI Z136.2, Standard for the Safe Use of Optical Fiber Communications Systems Utilizing Laser Diode and LED Sources, 1988.

h. ANSI T1.624, Telecommunications B-ISDN User Network Interfaces, Rates and Format Specification

i. ANSI T1.627, ATM Layer Functionality and Specification

j. ANSI T1.629, Telecommunications B-ISDN ATM Adaptation Layer, 3/4 Common Part Functionality and Specification

k. ANSI T1.630, B-ISDN ATM Adaptation Layer Constant Bit Rate Service Functionality and Specification

l. EIA-STD-RS-359, Standard Colors for Color Identification and Coding

m. EIA-STD-RS-455, Standard Test Procedures for Fiber Optic Fibers, Cables, Transducers, Connecting and Terminating Devices

n. IEEE 802.1I, Supplement to Media Access Control (MAC) Bridges Fiber Distributed Data Interface (FDDI)

o. IEEE 802.2, Logical Link Control for FDDI

p. IEEE 802.3, Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications

q. IEEE 802.4, Token-Passing Bus Access Method and Physical Layer Specifications

r. IEEE 802.5, Token Ring Access Method and Physical Layer Specifications

s. IEEE 802.6, Distributed Queue Dual Bus (DQDB) Metropolitan Area Network (MAN)

t. ISO/IEC 8802-2, Information Processing Systems - Local Area Networks - Part 2: Logical Control

u. ISO/IEC 8802-3, Information Processing Systems - Local Area Networks - Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications

v. ISO/IEC 8802-4, Information Processing Systems - Local Area Networks - Part 4: Token-Passing Bus Access Method and Physical Layer Specification

w. ISO/IEC 8802-5, Information Processing Systems - Local Area Networks - Part 5: Token Ring Access Method and Physical Layer Specification

OTHER PUBLICATIONS

a. Fiber Optic Networks, Paul Green, Jr., 1993

b. Technical Reference Pocket Guide, SynOptics, 1994

CHAPTER 3. GENERAL INFORMATION

3-1. FIBER OPTICS TECHNOLOGY OVERVIEW

a. A Brief History of Fiber Optics. The creation and development of fiber optic technology was prompted primarily by the need for increased user data rates and system capacity. Applications such as video, multimedia teleconferencing and medical image processing and distribution require transmission systems having high data rates and very low bit error ratios. Some of these applications require user data rates of 1 Gbps or higher and bit error ratios of 10^{-9} or lower. By the end of 1990, more than 5 million miles of optical fiber had been installed in the U.S. Future transmission systems will predominantly use optical fiber to carry information between fixed points, while radio communication means will carry information between fixed points and mobile or remote users.

b. Basic Operation of a Fiber Optic System. The optical fiber consists of a central core which guides light. The fiber core is covered by a cladding layer, which in turn is covered by a thin, protective overcoat; often one or more layers of protective sheathing or buffer material are added. The core and cladding materials are glass, while the overcoat and buffer material is plastic. The propagating field is guided through the fiber by virtue of the fact that the refractive index of the core is slightly greater than that of the cladding.

Light is generated on the transmit end of the optical fiber transmission path by either a light-emitting diode (LED) or a laser diode. The information signal is retrieved from the light at the far end of the transmission path by detecting the signal with a positive-intrinsic-negative (PIN) diode or an avalanche photodiode (APD).

The physical effects that occur to light propagating in optical fiber, such as dispersion and multimode distortion, are microscopic at the local level, but are greatly multiplied over the length of the transmission path. Therefore, signal degradation in optical fiber due to physical phenomena must be considered when designing the optical link, even though degradation is far less in optical fibers than in metallic transmission media.

3-2. BENEFITS AND RISKS

a. Benefits. The benefits of fiber optics technology can be summarized by the following:

(1) Small physical cable size. Each cable may contain a very high number of optical fibers. In situations where conduit space is limited, fiber optic cable may be preferred for this reason alone.

(2) High system capacity. Optical fibers support transmission at much higher data rates than metallic cables.

(3) **High bit rate per system user.** ATM provides for a minimum of 155 Mbps per user over fiber optic cable. FDDI allows users to share 100 Mbps.

(4) **High availability/reliability.** High availability of fiber optic transmission links may be achieved through redundant circuits (e.g., dual rings). Fiber optic equipment is highly reliable (e.g., a typical fiber optic transceiver has a Mean Time Between Failure (MTBF) of more than 1 million hours.

(5) **Capability to transmit long distances.** This can often be accomplished without the need for signal regeneration.

(6) **Long lifetime of system.** Fiber optic cables, when properly manufactured and installed, have an estimated 20-40 year life. Fiber optic equipment is also designed for long life.

(7) **Very low bit error ratio (BER).** A BER of between 10^{-9} and 10^{-15} can be achieved without the need for special coding techniques. The BER of a specific fiber optic link depends on the optical power budget. Commercial vendors specify power budgets based on a BER of 10^{-9}.

(8) **Very good communication security.** Undetected interception of signals from the fiber optic cable is very difficult.

b. Risks. Risks of using fiber optics technology have recently been ameliorated by the fact that the technology is essentially NDI/COTS and because interoperability of different vendors' equipment can be ensured through their membership in interoperability groups. Refer to Section 3-3 below for a discussion of the interoperability groups.

3-3. NETWORK STANDARDS AND PROTOCOLS

This section discusses the current and evolving fiber optic network standards, including Fiber Distributed Data Interface (FDDI), Fiber Optic Ethernet and Asynchronous Transfer Mode (ATM).

a. Fiber Distributed Data Interface (FDDI). FDDI is a token-passing LAN and MAN protocol that is defined primarily by ANSI X3T9.5 (Fiber Distributed Data Interface Standard), as well as ISO/IEC standards 8802-2, 8802-3, 8802-4, 8802-5. FDDI supports a total operational data rate of up to 100 Mbps. Hub architectures, in which the end users transmit data when they receive the token from the hub computer or server, are also supported by FDDI.

The FDDI standard ANSI X3T9.5 defines communication requirements in Layers 1 (Physical) and 2 (Data Link) of the Open System Interconnection (OSI) model, where Layer 2 is subdivided into the

Medium Access Control (MAC) (refer to IEEE 802.1I) and the Logical Link Control (LLC) (refer to IEEE 802.2). FDDI also defines the Station Management (SMT) function for Layers 1-7. As specified in ANSI X3.166, the physical media for FDDI may be fiber, copper, etc., allowing network segments to utilize different media if desired. Refer to ANSI X3.139, ANSI X3.148 and ANSI X3.166 for FDDI OSI protocol requirements.

When acquiring FDDI or other fiber optic systems and equipment, it is recommended that NAS project personnel ensure that the potential contractor be registered with a recognized interoperability group. Examples of these groups are ANSI X3T9.5 Committee for Standards; Advanced Network Test Center (ANTC), Sunnyvale, California; Interoperability Lab (IOL), University of New Hampshire, New Hampshire; European ANTC, Technical University of Berlin, Berlin, Germany.

At a minimum, the following documents, some of which are referenced in other sections of this document, should be used as references when FDDI networks are considered:

ANSI X3T9.5	Fiber Distributed Data Interface Standard
ANSI T1.105	Telecommunications -- Digital Hierarchy -- Optical Interface Rates and Formats Specifications (SONET) (FDDI and STS Path Signal Level) (ECSA); Supplement T1.105A
ANSI X3.139	Information Systems -- Fiber Distributed Data Interface (FDDI) Token Ring Medium Access Control (MAC)
ANSI X3.148	Information Systems -- Fiber Distributed Data Interface (FDDI) -- Token Ring Physical Layer Protocol (PHY)
ANSI X3.166	Information Systems -- Fiber Distributed Data Interface (FDDI) -- Token Ring Physical Layer Medium Dependent (PMD)

Table 1 presents the ANSI, ISO and IEEE standards applicable to fiber optic LANs and MANs.

b. Fiber Optic Ethernet. IEEE 802.3 specifies the algorithm for the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) algorithm used in the original 10 Mbps Ethernet standard, for which coaxial cable is the physical medium. Fiber Optic Ethernet is the implementation of the Ethernet standard using fiber optic cable as the physical medium. Like FDDI, Ethernet defines the Physical and Data Link layers of the OSI model. The original Ethernet specification contained timing constraints that were based on the maximum practical length (i.e., due to transmission losses) of a metallic coaxial transmission line between a multiport repeater and a node. This maximum length is less than 1 kilometer. State-of-the-art optical multiport repeaters employ timing circuitry that allows transmission distances up to 4 kilometers. Fast Ethernet, presently under development, will have the capability to transfer data at rates up to 100 Mbps. Switching arrangements will allow LANs and MANs to accommodate both Fiber Optic Ethernet and FDDI.

c. Asynchronous Transfer Mode (ATM). ATM is a protocol standard for fast packet switching at very high transmission rates. ATM is based on 53-byte cells that allow rapid switching at the hardware level. Forty-eight bytes of each cell comprise the information field; the remaining 5 bytes are used for overhead. Refer to Figure 1 for an illustration of the ATM cell structure.The ATM layer provides a point-to-point Virtual Channel Connection (VCC) between two ATM users. A number of virtual channels form a virtual path. ATM switching may be performed for ATM cells, virtual paths or virtual channels.

The ATM Adaptation Layer (AAL) performs all of the service- related functions needed to map services into ATM cells; these functions include handling of transmission errors and lost cells, flow control, timing and segmentation/reassembly. There are five types of AAL available, each of which meet special requirements of B-ISDN services.

ATM and FDDI networks are intended to be interoperable; however, additional equipment (e.g., bridges) is required to integrate ATM into existing FDDI networks. The ATM Layer and the ATM Adaption Layer (AAL) are used for switching/multiplexing and mapping services into ATM cells, respectively, in the B-ISDN Access Model.

Data rates that can be supported by ATM depend on transmission media and communications protocol. ATM supports 45 Mbps DS3, 100/155 Mbps bit encoded and 155 Mbps STP or UTP copper wire. ATM is media-independent and uses existing OSI physical layer components.

An important application for ATM is multimedia (integrated voice, data and video).

The basic ATM standards are in the process of completion by the CCITT/ANSI/ATM Forum. The ATM Forum, a consortium of vendors, carriers, users and research organizations, is the primary body within the U.S. developing implementation agreements from the international and national standards. ATM standards are expected to be completed by 1996.

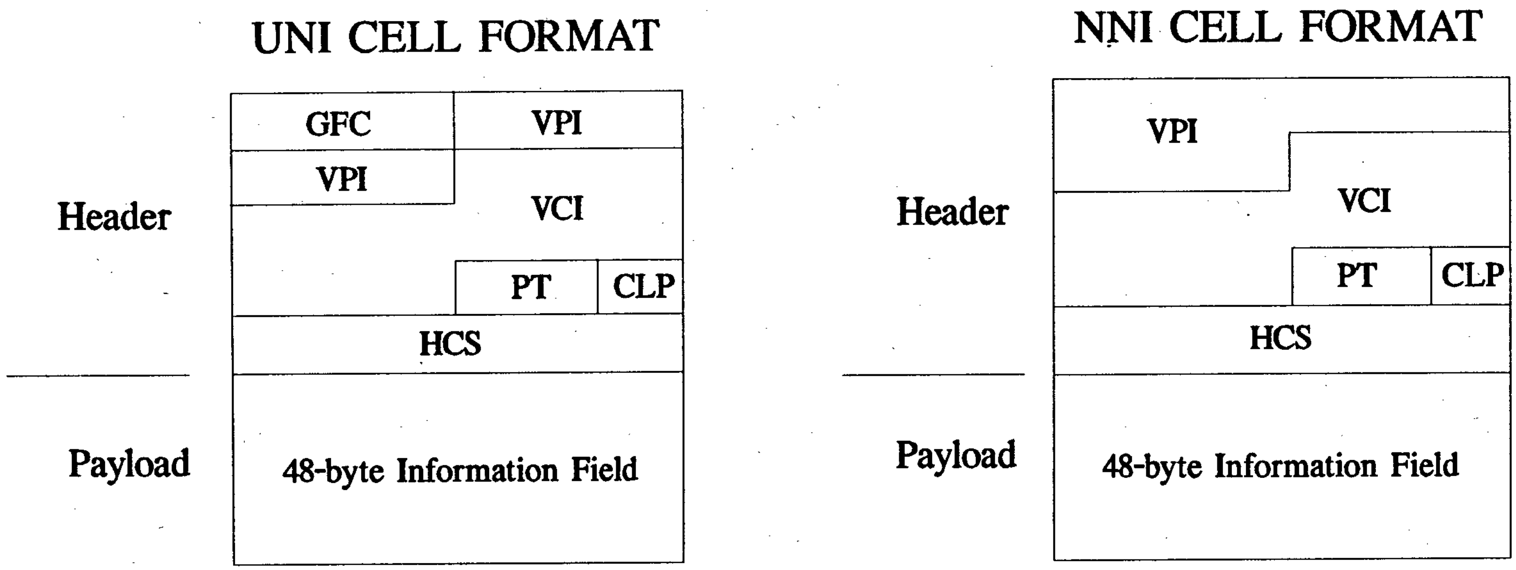
d. Fiber Channel. Fiber channel is a fiber optic communication standard based on ANSI X3T9.3, which defines the requirements for high speed packet switched networks using fiber optics. Network standards are being developed for Fiber Channel; Fiber Channel allows network nodes to be located up to several kilometers from the switch, supports up to 100 Mbps and has the capability to support a very large number of users.

e. Other Protocol Considerations. Other standards that should be considered in designing and implementing fiber optic systems and equipment are discussed in the following paragraphs.

(1) Government Open Systems Interconnection Profile (GOSIP). GOSIP is a mandatory, common set of Open System Interconnection (OSI) data communication protocols that enable systems developed by various vendors to interoperate and enable users of different applications on these systems to exchange information. Inclusion of FDDI in GOSIP is currently delayed. If

Table 1. Fiber Optic LAN and MAN Standards

SUBJECT	ANSI	IEEE	ISO
FDDI Standard	X3T9 . 5		
FDDI Media Access Control	X3 . 139	802 . 1I	9314 - 2
FDDI Physical Layer	X3 . 148		9314 - 1
FDDI Physical Layer Media Dependent	X3 . 166		9314 - 3
FDDI Hybrid Ring Control			9314 - 5
FDDI Logical Link Control		802 . 2	8802 - 2
CSMA/CD and Physical Layer		802 . 3	8802 - 3
Token Passing Bus and Physical Layer		802 . 4	8802 - 4
Token Ring Access Method and Physical Layer		802 . 5	8802 - 5
Distributed Queue Dual Bus MAN		802 . 6	



Legend:

GFC = Generic Flow Control
HCS = Header Check Sequence
NNI = Network Node Interface
CLP = Cell Loss Priority
PT = Payload Type
UNI = User Network Interface
VCI = Virtual Channel Identifier
VPI = Virtual Path Identifier

Figure 1. ATM Cell Structure

FDDI equipment is procured prior to GOSIP finalization, vendors should provide Station Management updates to final GOSIP requirements (e.g., by shipping new Read-only Memory (ROM)). FIPS PUB 146-1 (version 2) contains the requirements for GOSIP. GOSIP supports ISDN.

(2) Synchronous Optical Network (SONET). SONET is a new standard for optical transport developed by the Exchange Carriers Standards Association (ECSA) for the American National Standards Institute (ANSI). The SONET standard has been incorporated into the Synchronous Digital Hierarchy recommendations of the Consultative Committee on International Telegraph and Telephone (CCITT), currently referred to as ITU-T (International Telecommunication Union-Telecommunication Standards Sector).

SONET defines the digital hierarchy for fiber optic interfaces. This SONET hierarchy is based on a family of transmission rates having a base rate of 51.84 Mbps (Optical Carrier (OC) level 1). Higher SONET transmission rates are integer multiples of the base rate, where the highest SONET transmission rate is 2.488 Gbps. SONET can support services ranging from DS1 to B-ISDN (refer to paragraph 3-7); service adapters allow sub-DS1 rates to also be supported. SONET employs synchronous byte-interleaved multiplexing and supports FDDI. 155.520 Mbps (OC-3), 622.080 Mbps (OC-12) and 2.488 Gbps (OC-48) are the most widely supported rates.

The SONET frame format is usually depicted by a matrix of nine rows of 90 bytes each. The frame is transmitted byte-by-byte, beginning with byte one; the entire SONET frame is transmitted in 125 microseconds. The SONET network derives its timing from a Stratum 3 or higher clock. The SONET STS-1 frame is illustrated in Figure 2.

The primary SONET standards are ANSI T1.105, ANSI T1.106, and Bellcore technical reports TR-NWT-000253, TR-TSY-000496 and TR-NWT-000917.

3-4. FIBER OPTIC LINK

Figure 3 illustrates a typical full-duplex link using fiber optic cable. The Fiber Optic Medium Attachment Unit (FOMAU) performs the optical-to-electrical and electrical-to-optical signals. The use of regenerators (repeaters) is dependent on the distance involved; in general, distances of 20 km or less do not require regeneration.

3-5. NETWORK TOPOLOGIES

This section describes the primary fiber optic network topologies -- point-to-point, ring, active star, passive star and bus.

a. Ring. A ring network topology consists of repeaters joined by point-to-point links in a closed loop. Links of a ring configuration are unidirectional, i.e., data is transmitted in one direction only. All stations are attached to the network at repeaters. Because multiple communication devices

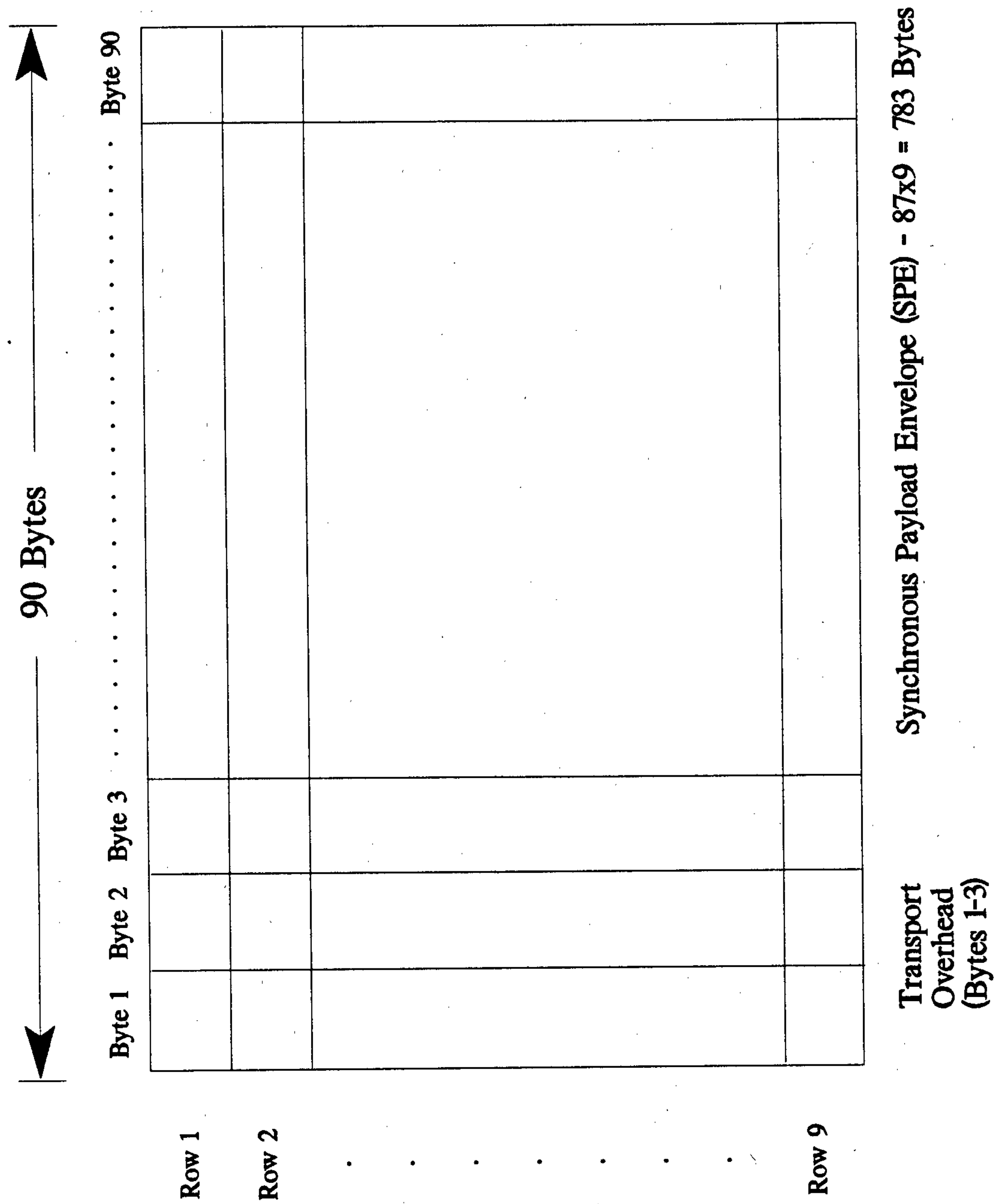
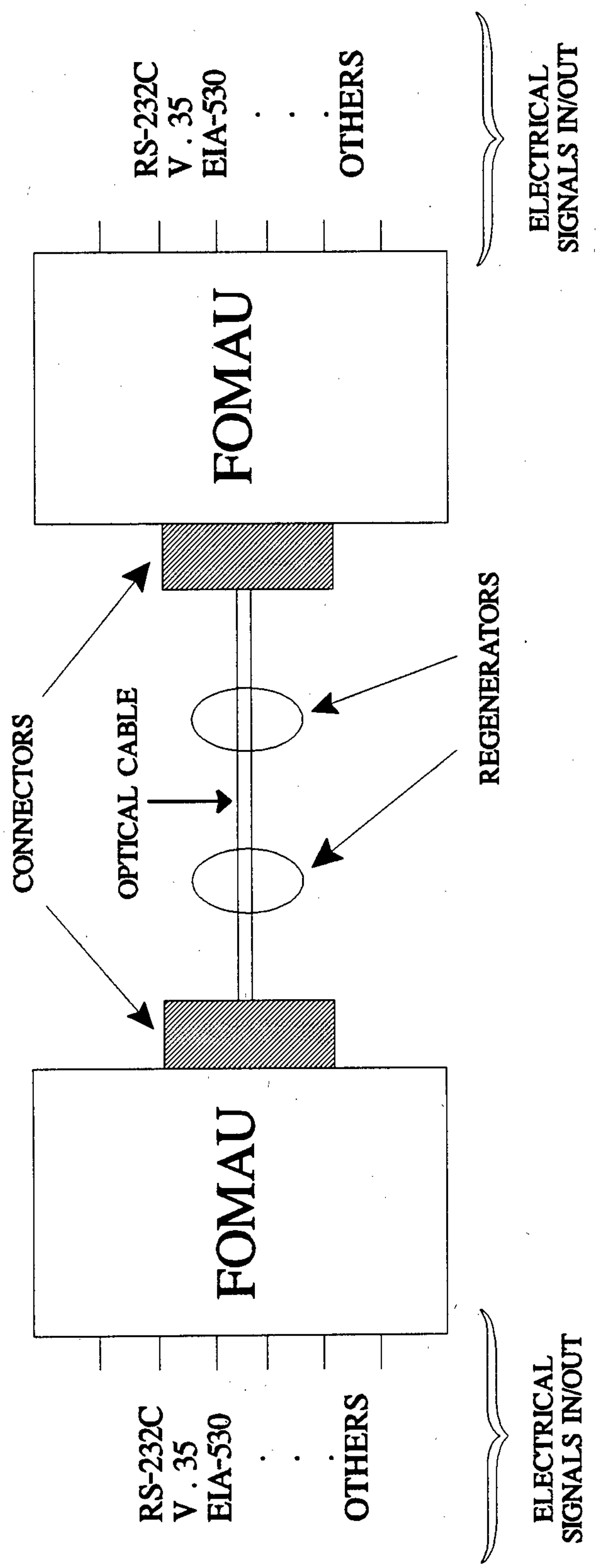


Figure 2 . SONET STS-1 Frame - 51 . 84 Mbps



FOMAU - Fiber Optic Medium Attachment Unit, Performs Optical-to-Electrical Conversion and Vice Versa

Figure 3. Fiber Optic Full Duplex Link

share the ring, network control is necessary to determine when stations may insert their data packets into the network.

b. Point-to-point. A point-to-point topology requires a dedicated path between the two communicating nodes. Equipment needed at both ends of the path depends on the application.

Three examples of ring topologies are (1) high-speed office networks, which involve distributed data bases, facsimile and graphics applications, (2) interconnected networks and (3) backend networks, in which computers are connected to mass storage devices. A token ring network employs a special bit pattern (token) that is circulated around the ring when all member stations are idle. Bit stuffing prevents the token bit pattern from appearing in the actual data. When a member station desires to transmit a data packet, it must first seize the token from the ring.

The Fiber Distributed Data Interface (FDDI) standard, which comprises a counter-rotating dual ring topology - a special configuration of a ring topology that provides two independent communication paths for all network members, thereby eliminating single points of failure.

Several ring topologies (e.g., FDDI and token ring) are illustrated in Figure 4.

c. Star. Active and passive star topologies are discussed in the following two paragraphs.

(1) Active Star. An active star topology incorporates an active star coupler (multiport repeater) to connect network users. Messages from one user to another must be processed by the active star coupler.

Both electrical and opto-electronic components are required for this type of network. The primary disadvantage of the active star topology is that the active star coupler is a potential single point of failure.

(2) Passive Star. A passive star topology is a star configuration that behaves like a bus configuration; i.e., transmissions from any device in the network are received by all other devices in the network. The number of devices that may comprise the passive star network and the distances between the passive star coupler and the network devices is dependent on the combined attenuation of optical connectors and optical cable as well as the number of ports at the coupler.

d. Linear Bus. The primary advantage of the linear bus topology is that data can be transmitted to all users simultaneously (broadcast). The primary disadvantage of the linear bus topology is that if a single connection is cut, the network will be split at that point, whereas in a star topology, a single cut connection isolates only one node of the network. Refer to IEEE 802.6, Distributed Queue Dual Bus (DQDB) Metropolitan Area Network (MAN). Network management for a linear bus system may be accomplished by several methods (e.g., token-passing bus).

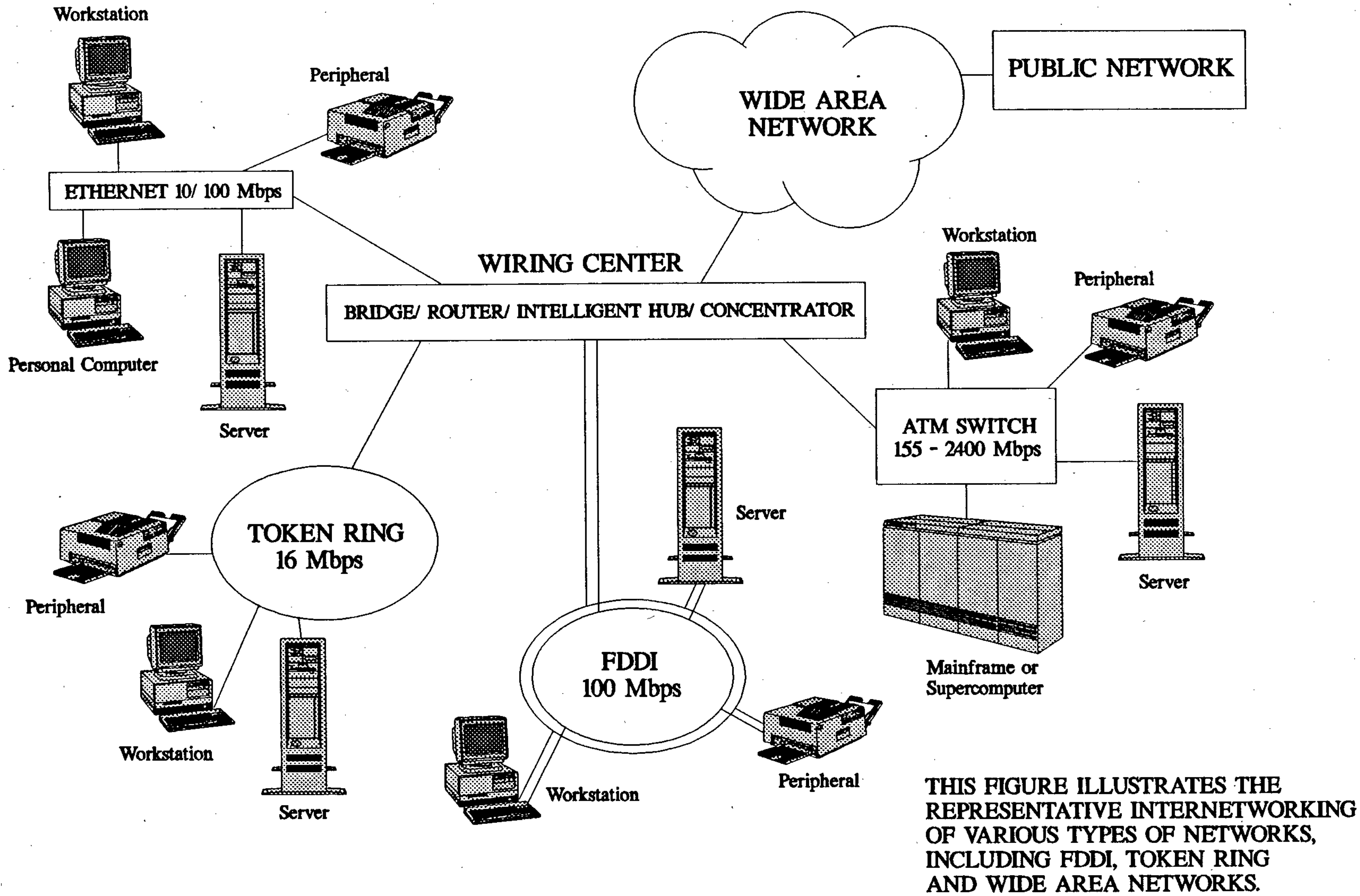


Figure 4. Universal Fiber Optic Network Architecture

Fiber optic network topologies are illustrated in Figure 5.

3-6. SPECIAL CONSIDERATIONS

a. Testing. Optical fibers should be individually tested during manufacture to withstand a minimum tensile load of 50 kpsi to ensure the absence of significant flaws in the optical material and long cable life.

b. Safety. Looking directly into the end of an optical fiber cable that has been disconnected from a connecting device, even when the optical fiber does not appear to be transmitting light, may injure the eye. ANSI Z136.2 states that when an optical connector is removed during service and an optical instrument (e.g., loupe) is used to view the end of an energized fiber, the radiant energy may impinge on the eye. Stripped optical fiber may be accidentally poked into one's skin and, if it snaps off, difficult or impossible to remove.

3-7. ISDN AND B-ISDN

a. Integrated Services Digital Network (ISDN). ISDN is an evolving concept of integrated communication networks that will be capable of supporting a wide range of voice, facsimile, data and other applications. ISDN includes a range of services that utilize a limited set of connection types and user-to-network interfaces. ISDN will be capable of supporting circuit switched and packet switched networks operating at a basic rate of 64 kbps; higher data rates will be accommodated as well. Furthermore, the protocols that are being developed for user access to ISDN exhibit a layered architecture and can be mapped into the OSI model. The transmission structure of an ISDN access link is based on the following channel types:

(1) B Channel - 64 kbps, used for digital data, digitized voice or a mixture of low data rate information.

(2) D Channel - 16 or 64 kbps, used to set up calls on B channels and for packet switching and low-speed telemetry data.

(3) H Channel - 384, 1536 or 1920 kbps, used for higher data rate information such as fast facsimile, video, high-speed data, high-fidelity audio and multiplexed data streams.

Standards for ISDN are in the process of being defined by CCITT and ANSI.

Candidate services for ISDN are shown in Table 2.

b. B-ISDN (Broadband ISDN). B-ISDN services, such as image and video, that require data rates higher than those provided by ISDN, require the evolution of technologies necessary to support these services. These technologies include:

(1) Optical fiber transmission for both trunks and subscriber lines. Whereas ISDN

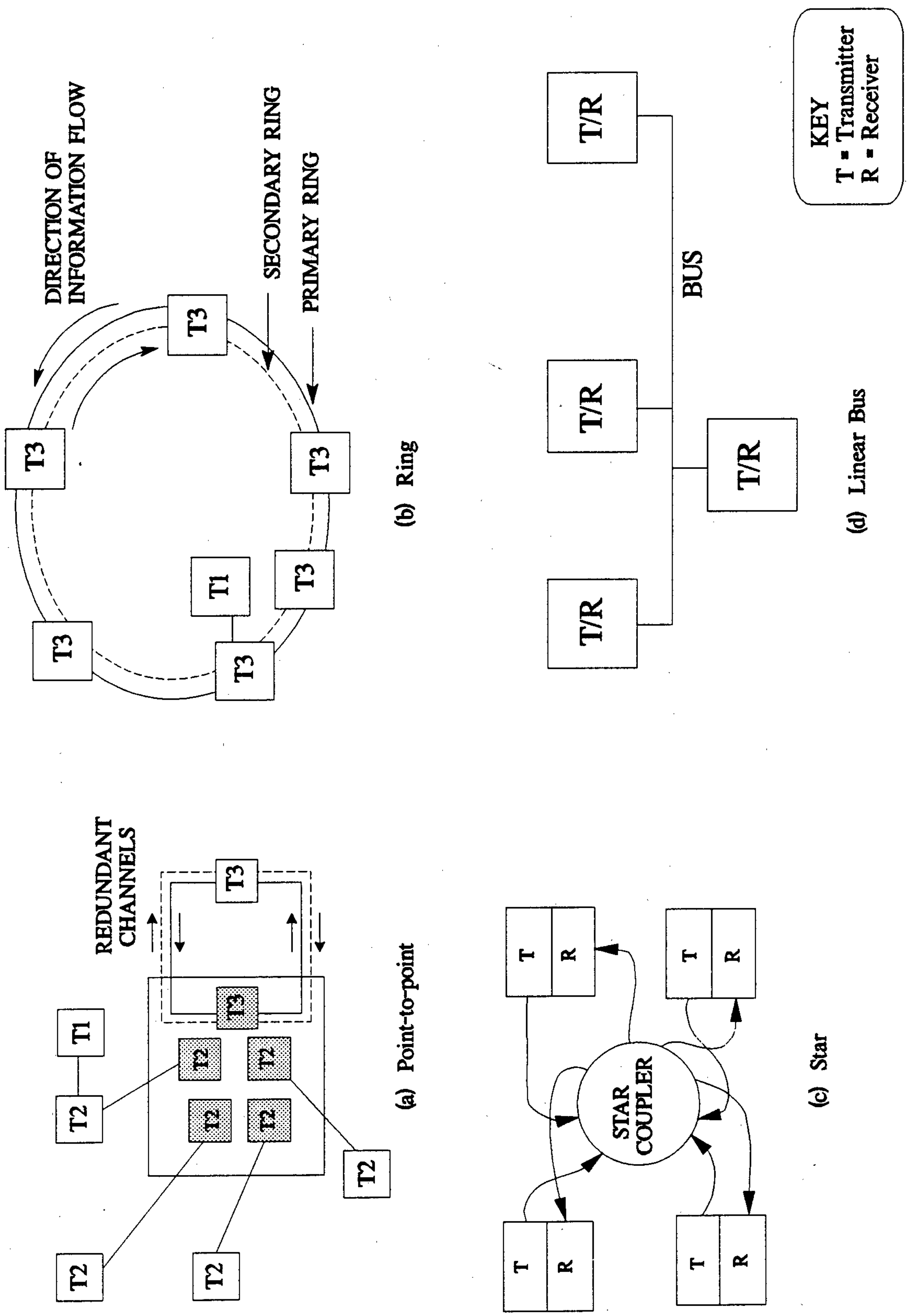


Figure 5. Fiber Optic Network Topologies

subscribers can be supported with twisted pair copper wire, B-ISDN subscribers will require optical fiber. The data rate for transmission from the network to subscriber will have to be approximately 622 Mbps to accommodate multiple video distribution. The data rate from the subscriber to the network is expected to be about 155 Mbps.

(2) High speed switching (e.g., ATM or frame relay)

(3) High quality video cameras and monitors

CCITT and ANSI are presently developing standards for B-ISDN; these standards recommend two types of SONET access interfaces over single-mode fiber: 155 Mbps User Network Interface (UNI), which uses an STS-3c signal format with OC3 as the optical interface and 622 Mbps UNI, which uses an STS-12c signal format with an OC12 optical interface. The ANSI standards for B-ISDN are:

(1) ANSI T1.624, Telecommunications B-ISDN User Network Interfaces, Rates and Format Specification

(2) ANSI T1.627, ATM Layer Functionality and Specification

(3) ANSI T1.629, Telecommunications B-ISDN ATM Adaptation Layer, 3/4 Common Part Functionality and Specification

(4) ANSI T1.630, B-ISDN ATM Adaptation Layer Constant Bit Rate Service Functionality and Specification B-ISDN interactive and distribution services are expected to be available before the turn of the century. Figure 6 compares B-ISDN, OSI and ISDN Access Models.

Table 2. Candidate Services for ISDN

Data Rate	Telephony	Data	Text	Image
Digital Voice (64 kbps)	Telephone Leased Circuits Information Retrieval (by Voice Analysis and Synthesis)	Packet Switched Data Circuit Switched Data Leased Circuits Telemetry Funds Transfer	Telex Teletex Leased Ckts Videotex Facsimile	Slow-scan TV Applications. Most useful for single frame, but limited-motion color TV is possible.
		Information Retrieval Mailbox Electronic Mail Alarms	Info Retrieval Mailbox Electronic Mail	Info Retrieval Surveillance
Wideband (greater than 64 kbps	Music	High-Speed Computer-to-Computer		TV Conference Teletex Videophone Cable TV

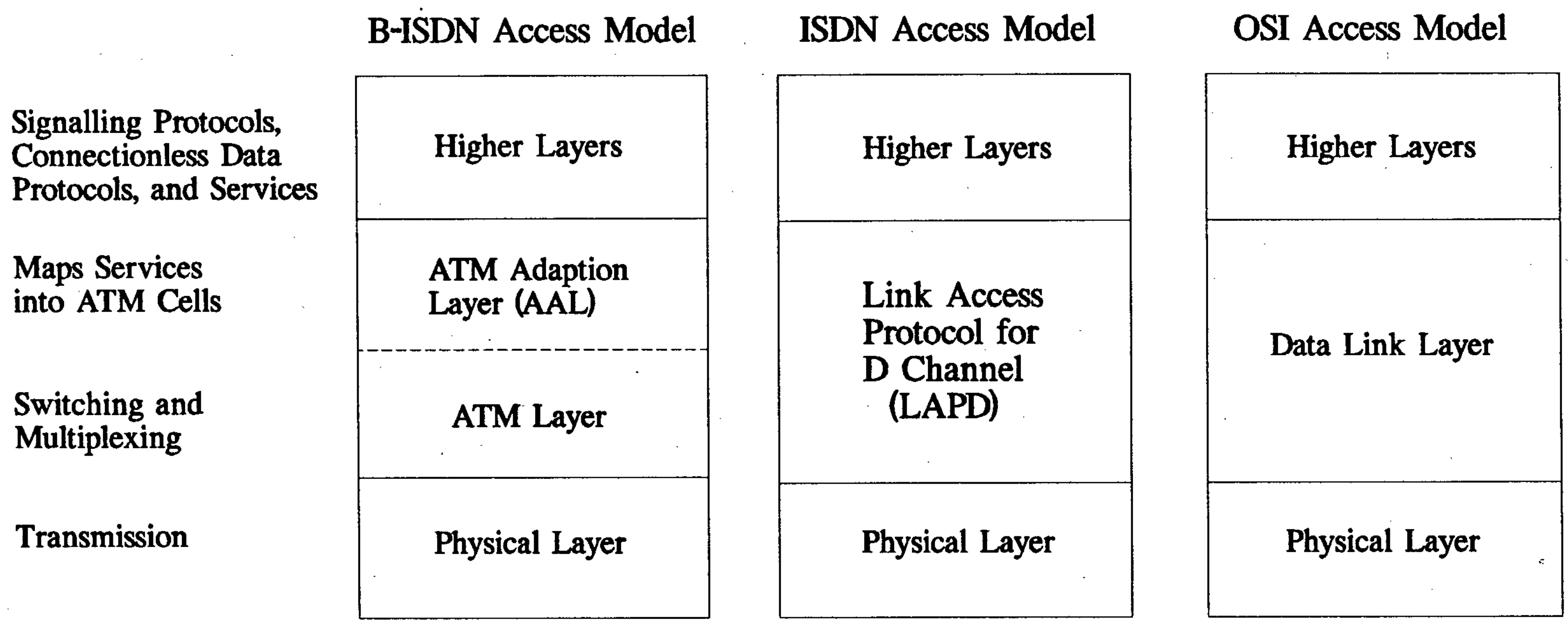


Figure 6. B-ISDN, ISDN and OSI Access Models

CHAPTER 4. PLANNING TELECOMMUNICATION NETWORKS

4-1. SELECTION OF TRANSMISSION MEDIUM

Prior to the selection of a transmission medium, a trade-off analysis should be performed to determine the most practical and effective method of information transfer/distribution. General criteria should be used to evaluate the capabilities of competing transmission technologies; these capabilities include being able to provide users with the necessary bandwidth and connectivity by a method resistant to catastrophic failure. Table 3 shows the primary communication characteristics of various transmission media.

A cost benefit analysis supporting the chosen transmission method should also be performed.

4-2. CURRENT FAA APPLICATIONS

The following are FAA facilities that use fiber optic transmission. Many of these facilities are located around airport terminals and runways. Refer to Appendix A for a specification guide for airport fiber optic cables.

a. Runway Facilities. Point-to-point or ring fiber optic networks, or a combination thereof, may be used to connect the following runway facilities with each other or with other airport facilities. Runway facilities transmit or exchange data, whereas airfield facilities transmit or exchange voice or data.

(1) Middle Marker (MM)

(2) Far Field Monitor (FFM)

(3) Medium-Intensity Approach Lighting System with Runway Alignment Indicator Light and Approach Lighting System with Flashers-II (MALSR and ALSF-II)

(4) Inner Marker (IM), Localizer (LOC)

(5) Microwave Landing System (MLS)

(6) Glide Slope (GS)

(7) Runway Visibility Range (RVR)

Table 3. Characteristics of Various Transmission Media*

Medium	Distance Between Nodes	Potential for Growth	Propagation Delay **	Availability/ Reliability	Bandwidth ***
UTP Copper	100 m	Low/Med	Low	Med	1 MHz
STP Copper	100 m	Low/Med	Low	Med	1 MHz
Multimode Fiber	2 km	High	Low	High	≈ 400 MHz
Single-mode Fiber	20 km	High	Low	High	Many GHz
Plastic	100 m	Low	Low	High	Less than 200 MHz
Microwave	30-40 mi	Low	Low	Low/Med	20 MHz - 1 GHz
Satellite	Unlimited, When nodes are Within Footprint	Low/Med	Very High	Med	500 MHz per Satellite

UTP = Unshielded Twisted Pair
STP = Shielded Twisted Pair

* NOTE 1: Relative comparison only.

** NOTE 2: The propagation delay is a function of the distance traveled. The velocity of light in a vacuum is 300,000 km/sec. Velocity of light through fiber optic cable is about 200,000 km/sec. Therefore, the combined uplink and downlink propagation delay for geostationary satellite link is about 0.250 sec; for fiber and copper cable, delay is about 4.5 μs/km; microwave link propagation delay is about 3 μs/km.

*** NOTE 3: The available bandwidth of an optical fiber depends on specific fiber characteristics and the wavelength and linewidth of the optical signal. For terrestrial transmission media, the supportable data rate is an inverse function of distance. For metallic media, e.g., coaxial cable, bandwidth is inversely proportional to the square of the length. For optical fibers, it is inversely proportional to the length.

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(8) Precision Approach Path Indicator (PAPI)

(9) Runway Visibility Range Midfield (RVR-MF)

(10) Remote Transmitter/Receiver (RTR) division level at the FAA

b. Airfield Facilities. The following airfield facilities at FAA airports are candidates for fiber optic connectivity:

(1) Remote Transmitters/Receivers (RTR) (voice)

(2) Airport Surveillance Radar (ASR) (data and video)

(3) Airport Surface Detection Equipment (ASDE) (data)

(4) Airport Traffic Control Tower (ATCT) (voice)

(5) Terminal Radar Approach Control (TRACON) (voice)

(6) Doppler VHF Omnidirectional Range (DODR) (data)

c. Video Links. Terminal Radar Approach Control (TRACON) and other FAA terminal areas have requirements to distribute wide-band analog video to Digital Bright Radar Indicator Tower Equipment (DBRITE) located in FAA towers. Fiber optic transmission should be analyzed for cost/benefit for DBRITE video links and for the eventual replacement of existing Television Microwave Links (TMLs). DBRITE links handle wide-bandwidth (15.5 MHz), uncompressed, analog video.

d. Local Area Networks/Wide Area Networks (LANs/WANs). New building installations include, but are not limited to, Metroplex Control Facilities (MCFs) and airport buildings (e.g., ATCTs). Fiber optic systems and equipment should be analyzed for cost/benefit to provide intrafacility communication in new FAA buildings.

e. Remote Maintenance Monitoring (RMM). Some links to remote locations for the purpose of obtaining remote maintenance monitoring data might best be handled by a fiber optic system, especially if the fiber link were already in place for the transfer of other data from the remote location.

f. Point-to-point Circuits. Point-to-point circuits (e.g., those connecting long range radars and centers) should be analyzed to determine the cost/benefit of fiber optic transmission.

4-3. FIBER OPTIC NETWORK COMPARISONS

Table 4 illustrates the characteristics of several fiber optic network types.

Table 4. Comparison of Fiber Optic Network Characteristics

Characteristic	Ethernet	Token Ring	FDDI	ATM
Shared Bandwidth	Yes	Yes	Yes	No
Data Rate	10 Mbps	4/16 Mbps	100 Mbps per Ring	Up to 155 Mbps and 622 Mbps
Local Area Net	Yes	Yes	Yes	No
Wide Area Net	No	No	Yes	Yes
No. of Users	Medium	Low/Med	Medium	Very High
Max Distance Between Nodes	2 km MMF 20 km SMF	100 m UTP 2 km MMF	2 km MMF 20 km SMF	2 km MMF 20 km SMF

KEY:
MMF = Multimode Fiber
SMF = Single-mode Fiber
UTP = Unshielded Twisted Pair

4-4. USING FAA-STD-049 FOR EQUIPMENT AND SYSTEM ACQUISITION

This section presents instructions for tailoring the FAA-STD-049 (FAA Standard for Fiber Optic Telecommunication Systems and Equipment) for use in FAA acquisitions, procurements and evaluations. Tailoring is the process of selecting appropriate portions of a standard for citation in other documents (e.g., acquisition documents). Tailoring occurs at the major section, subsection or paragraph level and consists of the adoption, elimination, modification or substitution of requirements.

The FAA Standard for Fiber Optic Telecommunication Systems and Equipment may be cited in its entirety if communication interfaces are not known in advance (i.e., are to be determined through planning, system engineering and analysis). Citing the standard in its entirety does not prevent the contractor from requesting tailoring later in the program. At some point in time, specific standards should be provided to the contractor.

The tailoring process involves the evaluation of each paragraph or requirement statement in applicable standards to determine their pertinence to the equipment or systems being procured.

Then, all pertinent paragraphs and requirement statements are combined to form the tailored standard which is referenced in the fiber optic equipment/system procurement package. The steps for developing the procurement package are:

1. Identification of the applicable standards documents based on the documents and technical information contained in FAA-STD-049.

2. Detailed review of applicable standards documents and selection of the most appropriate statements and paragraphs that support the requirements under consideration.

3. By reference, incorporation of the selected statements and paragraphs into the fiber optic equipment/system procurement package.

The contractor may request or recommend tailoring at any time during acquisition, update or modification contracts or during advanced development or research contracts.

The contractor may also request waivers and offer alternatives for the applicable design criteria and guidelines, respectively. If the procurement is for NDI or COTS items, the tailoring of the standard is relatively straight-forward. A tailored checklist should be provided to the contractor, who in turn may submit equipment bids or use the tailored checklist as part of an equipment selection process.

Tailoring may be performed either by the FAA only or in cooperation with the selected contractor.

CHAPTER 5. FIBER OPTIC TRANSMISSION EQUIPMENT

5-1. FIBER OPTIC NETWORK EQUIPMENT

a. Switch. A switch is a multiport, data link layer device that creates a temporary switched path over which packets are sent directly to a destination Media Access Control (MAC) address.

b. Router. A router is a network layer device that uses protocols to direct packets to their destination. Routers are similar to bridges in that they prevent local messages from reaching the rest of the network. However, unlike bridges, which simply forward data, routers actually direct data packets to their final destination over the least expensive available path. Routers offer the most flexibility for connecting individual LANs to create a complex network. A router allows the creation of mesh topologies, which feature a number of possible paths between any two points in the network. Routers examine the network layer protocol of each data packet addressed to them.

c. Bridge. A bridge is an MAC-layer device that forwards or discards packets based on MAC address. Bridges offer the simplest solution for connecting LAN segments when creating an extended network. Bridges join two or more LANs, creating a single network that is independent of the protocol used. The bridge determines whether or not to forward a data packet to the rest of the network by examining the packet destination address.

5-2. FIBER OPTIC COMPONENTS

The primary fiber optic components are discussed in the following paragraphs.

a. Transceiver. A transceiver is a combination of both transmitter and receiver. A transceiver must be used when simultaneous two-way communication is required. Transceivers are generally available in both single-mode and multimode versions. Refer to the discussion of transmitters and receivers in the next paragraphs.

b. Transmitter.

(1) Light-emitting Diode (LED). An LED may couple -15 to -17 dBm into a 62.5/125 μm fiber. The amount of power coupled into the fiber depends on the fiber characteristics. LEDs have a greater beam divergence than laser diodes.

(2) Lasers

(a.) Laser diode. A laser diode is an optical source. The light produced by a laser diode is essentially monochromatic and has an appropriately narrow exit angle, resulting in efficient coupling to the optical fiber. Laser transmitters must be used with single-mode fiber.

(b.) Fiber Amplifier. A fiber amplifier is a rare earth-doped device having better noise performance and lower coupling losses than optoelectronic amplifiers (analog regime) or optoelectronic regenerators (digital regime). Current rare earth-doped fiber amplifiers have a gain of 22 dB over a 35 nm bandwidth from a 1480-nm laser diode. Consequently, much longer transmission distances over fiber links are possible without the use of regenerators.

c. Receiver. The primary type of fiber optic receiver is a direct detection receiver. In this type of receiver, a photodetector converts the stream of incident photons into a stream of electrons; the stream of electrons (current) is amplified and a determination is made whether the current is primarily above or below a certain threshold.

d. Repeater. The two primary types of optical repeaters are optoelectronic amplifiers and regenerators and doped-fiber amplifiers, both of which are discussed in the laser transmitter section above.

e. Directional Coupler. A directional coupler is also referred to as a splitter - a passive devices that distribute optical power among two or more ports. It is customary to refer to couplers in terms of the number of input and output ports; for example, a device which has 16 input ports and 16 output ports is called a "16 X 16" star coupler and is comprised of a total of 32 couplers.

f. Modem. Fiber optic modems are useful in point-to-point, multi-drop, ring and bus applications. Data rates between about 300 bps and 2.048 Mbps can be accommodated by a range of modems. A number of standard communication interfaces are available, including RS-232, RS-366, RS-485, RS-530, T1/E1 and V.35. Modems are available for synchronous and asynchronous applications and come in both multimode and single-mode versions. Some fiber optic modems can function as two-channel multiplexers if the control channel is used as a data channel.

g. Multiplexer. This device is used to transmit or receive multiple signals simultaneously over the same transmission medium. Single-mode or multimode fiber may be used with these devices.

h. Optical Multiport Repeater. An optical multiport repeater is an active digital optoelectronic device having a large number (usually a minimum of four) of optical I/O ports. An input to any port is retransmitted at the output of all ports. The optical multiport repeater may also perform such functions as signal retiming and regeneration.

i. Fiber Optic Connector. The use of the straight-through physical contact (ST-PC) type of connector is recommended. For patch panel applications, a complimentary connector, the fixed-shroud duplex (FSD) connector is recommended. The Amphenol 906-style SMA, an older design is also acceptable if the ST-PC type is not available. In cases where proprietary connectors must be used, hybrid cables should also be used.

5-3. FIBER OPTIC CABLES

a. Loose-buffered Cable. Loose-buffered cables contain fibers that are not in intimate contact with the buffer and are therefore isolated from axial and transverse forces of small magnitude applied to the cable. These cables are best suited to long haul applications where flexibility of the cable is not a primary consideration.

b. Tight-buffered Cable. Tight-buffered cables contain optical fibers that are in intimate contact with the buffer, but are cushioned from transverse and axial loads applied to the cable. The primary advantage of tight-buffered cable is that repetitive transverse or axial forces applied to the cable will not cause the cable to break.

The acrylate coatings on fibers in tight-buffered cables are overcoated (tight-buffered) with high-performance plastics having the capability to withstand submersion in water for indefinite periods without degradation. The elimination of the requirements for stiff protection elements and gel filling in these cables provides for high degrees of flexibility, capability for direct connection, mechanical ruggedness and flame retardancy. Tight-buffered breakout style cables are suitable for general purpose short distance applications and are easily terminated and connected. They are suitable for aerial lashing and for pulling into underground ducts; they can be buried in sand and soil and may be overarmored for direct burial in rocky or rodent-infested terrain.

Tight-buffered, non-breakout style cable may be used for short haul applications only and should not be buried without overarmoring nor lashed to a messenger if the cable diameter is less than 8 mm. Cable of diameter less than about 6.5 cm (2.5") is subject to rodent attack; when the cable diameter is greater than about 2.5 inches, most rodents cannot obtain sufficient tooth purchase to do much damage. Duct having an outside diameter of 2.5" or more (or if direct-earth-buried, armored cable) should be used.

The generic requirements for airport fiber optic cables are provided in Appendix A of this document.

Figures 7 and 8 illustrate typical configurations of tight-buffered breakout cable and loose-buffered cable, respectively. Figure 9 shows a typical zip cord construction.

c. Types of Fiber.

(1) Single-mode Fiber -- Single-mode optical fiber allows only the lowest order bound mode (i.e., electromagnetic field configuration) to propagate through the fiber at the wavelength of interest. Single-mode fiber operation eliminates the bandwidth reduction caused by modal distortion. Single-mode fiber is best-suited to high data rate requirements, such as wide-bandwidth video.

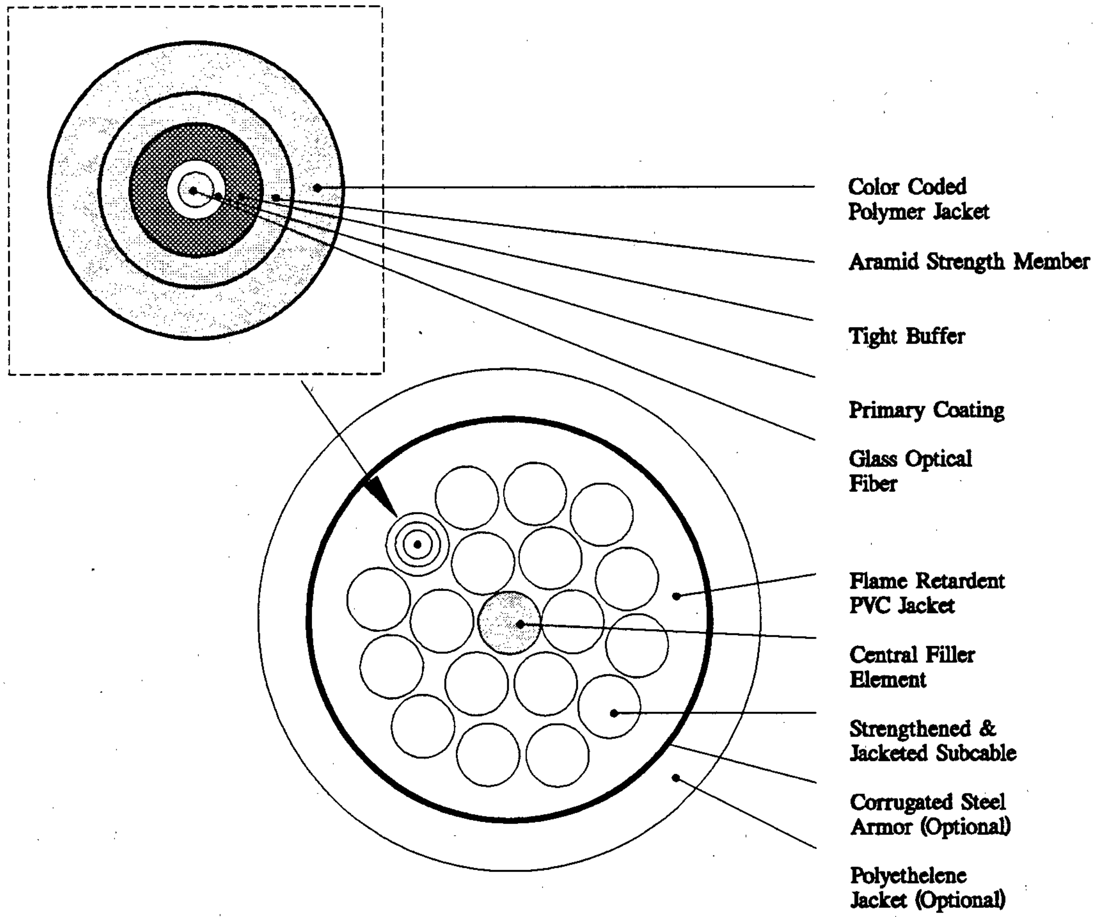

Figure 7. Typical Tight-buffered Breakout Cable

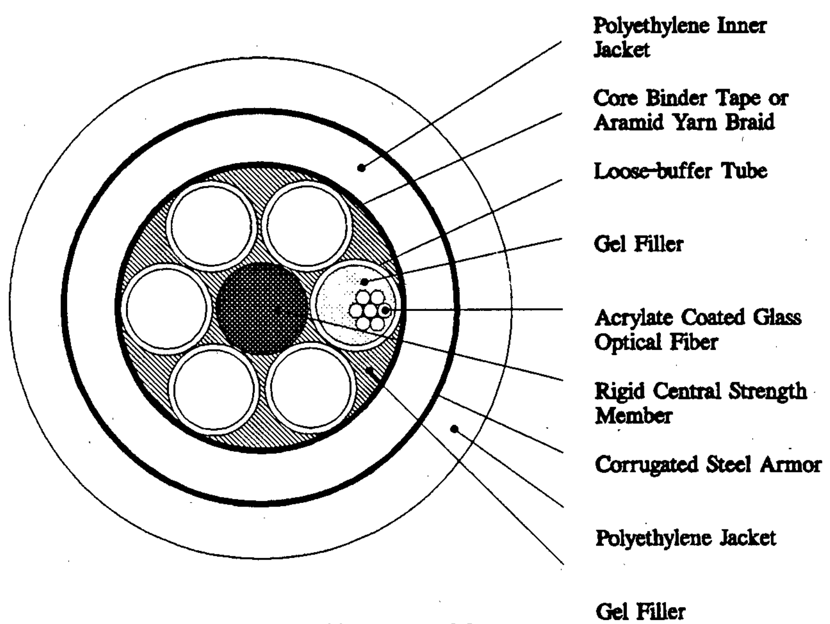

Figure 8. Typical Loose-buffered Cable

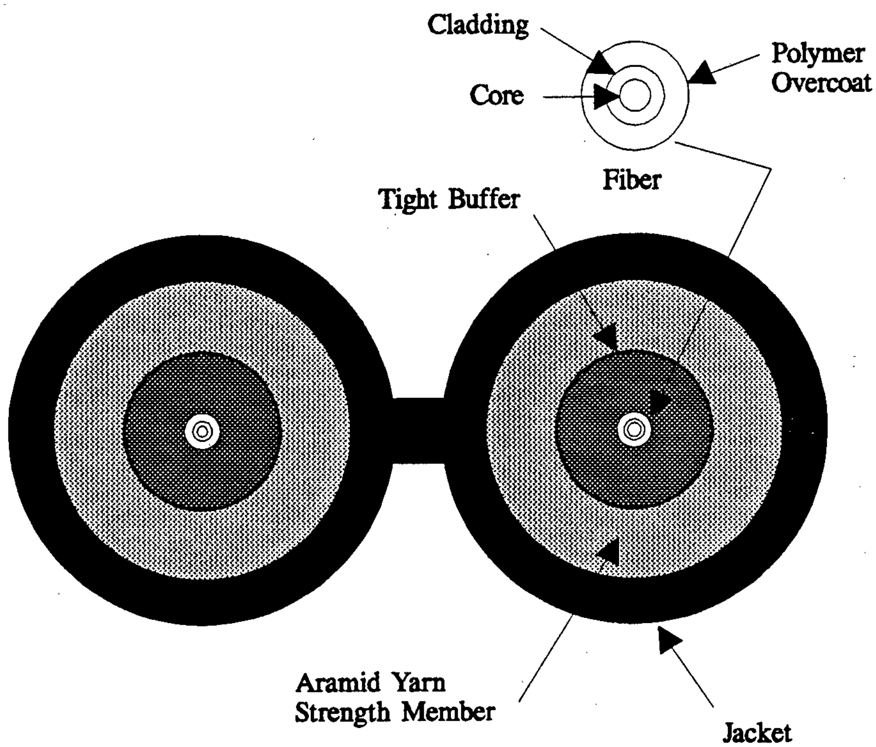

Figure 9. Cross-section, Typical Tight-buffered Duplex Zip Cord

The primary characteristics of single-mode fiber are:

(a.) Supports high data transfer rates;

(b.) Requires regeneration every 30 miles;

(c.) Cannot use a conventional LED optical source, i.e., must use a laser source.

Single-mode fiber requires a transmitter having a source with minimal beam divergence, i.e., a laser diode.

ANSI/EIA/TIA-559 defines requirements for single-mode fiber optic systems; characteristics of various types of single-mode fiber cable are provided in CCITT Recommendations G.652, G.653 and G.654.

(2) Multimode Fiber -- While single-mode fibers have only one solution to Maxwell's equations for the wavelength of interest, multimode fibers may have as many as a hundred or more. Multimode fiber receives and emits a broader cone of light rays (i.e., they have a higher numerical aperture) than single-mode fiber. Multimode fiber may be either step-index or graded-index, the latter of primary interest for FAA applications; step-index fiber is not recommended for FAA applications.

Graded-index multimode fiber has the following characteristics:

(a.) Captures approximately 18-20 dB more light from a conventional LED source than single-mode fiber. Even when used with an LED transmitter, multimode fiber can tolerate a limited amount of passive splitting for small networks.

(b.) Using a conventional LED source, requires regeneration at intervals of approximately 2-6 miles (3-10 kilometers), depending on the operating wavelength. Regeneration intervals may be longer if a laser diode optical source is used.

(c.) Possesses a lower bandwidth • length product than single-mode fiber (typically less than 1 GHz • kilometer; in most cases the product is lower, although fibers possessing products as high as 3 GHz • km have been produced). In practice, physical limitations of LED transmitters, with which multimode fiber is usually used, restrict transmission bandwidth to approximately 200 MHz; the operating bandwidth is usually less than 200 MHz and is dependent on the performance of the LED transmitter used. Short graded-index multimode fiber is capable of supporting much higher data rates when used with laser transmitters.

(d.) Generally exhibits lower bending losses than single-mode fiber (an important characteristic in cases when cables are dressed to short bending radii (e.g., in LAN applications). In the near future, some types of single-mode fiber will have very low bending losses. Multimode and single-mode fiber transmission are illustrated in Figure 10.

(3) Plastic Fiber -- Plastic optical fiber (POF) is an alternative to silica-based fiber, but for very short runs only. The attenuation per unit length for plastic fiber is too great for applications where runs longer than about 50 meters are involved. Because it is possible to fabricate fiber having a much larger diameter core (nominally 500-1000 μm) using plastic (as opposed to silica), lower cost optical sources, detectors and connectors can be implemented in a fiber optic network. Furthermore, a POF core provides sufficient mechanical strength for a cable; an additional strength member is not required and a cladding thickness of only approximately 5 μm may be used. It should be noted, however, that most COTS equipment currently manufactured has optical connectors designed primarily for glass fibers; therefore, in most installations, glass fibers are recommended.

The primary requirements for airport fiber optic cables is provided in Appendix 1 of this document.

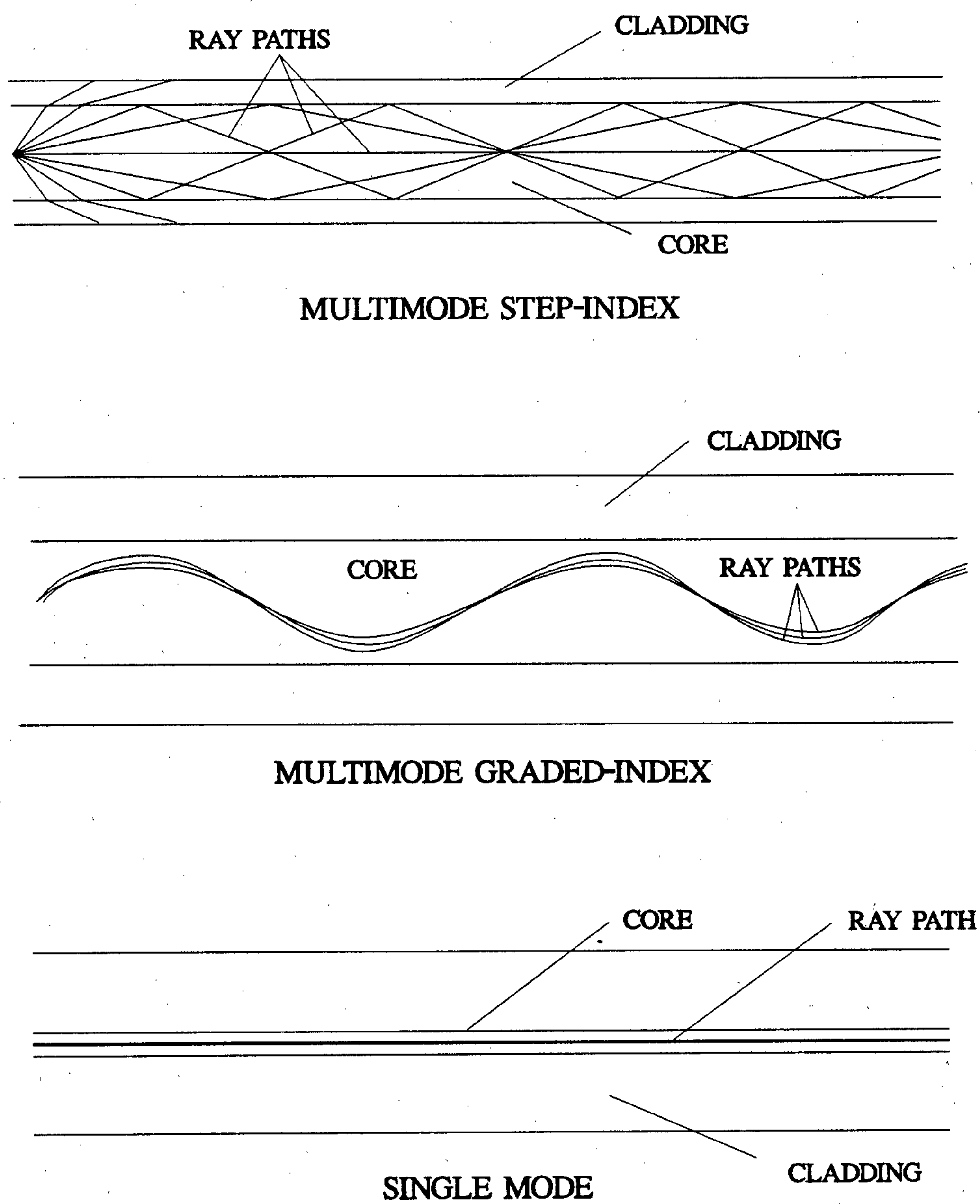

Figure 10. Types of Optical Fiber Showing Propagation of of Light Along Fiber

CHAPTER 6. IMPLEMENTATION

6-1. NEW BUILDING CONSTRUCTION

The following guidelines should be used for new building construction:

Refer to EIA/TIA 568, Commercial Building Telecommunications Wiring Standard for commercial wiring practices. The following paragraphs describe the types of optical fiber that should be used for the four primary applications.

(1) Workgroup. 62.5/125 micrometer multimode optical fiber should be used for workgroup applications where distances involved are greater than approximately 100 meters. 62.5/125 micrometer multimode fiber or plastic optical fiber (POF) may be used when distances involved are relatively short (i.e., less than 100 meters).

(2) Floor. Optical fiber and ancillary equipment should be used in all applications on a floor of a building where distances greater than approximately 100 meters are involved. Optical fiber should also be used when distances involved are relatively short. Unshielded twisted pair copper or plastic optical fiber should only be used in instances where it is shown to be the most cost-effective solution; however, glass fiber is preferred for most applications.

(3) Building. 62.5/125 micrometer multimode fiber should be used for all applications in buildings having multiple floors. When planning new horizontal building wiring, refer to Technical Bulletin, "Unshielded Twisted Pair Cable Information Guide," TB520-235US, which defines characteristics of Category 3, 4 and 5 UTP cables and provides a list of preferred UTP cables.

(4) Metropolitan Area Network (MAN) and Wide Area Network (WAN). 62.5/125 or 50/125 micrometer multimode optical fiber should be used for WANs, unless very long distances are involved (more than about 10 kilometers), in which case 8.3/125 micrometer single-mode fiber should be used.

6-2. SITE SURVEY

For large installations, site surveys should be performed prior to ordering any equipment. Site surveys should include all existing interconnections, including cabling, cross-connect fields, punch-down blocks, terminating hardware, electrical outlets, building grounding, etc. Site surveys should also include physical and logical network layout and critical segments. Site surveys should determine the users of the network(s), the number of stations that can be supported, growth that can be supported by new cabling and the requirement for network management. The information gathered during the site survey should be used to plan a new layout and to order equipment.

6-3. TESTING

Each fiber should have been proof tested during the manufacturing process at a minimum of 50 kpsi. Test requirements for fiber optic equipment are contained in EIA-STD-RS-455, Standard Test Procedures for Fiber Optic Fibers, Cables, Transducers, Connecting and Terminating Devices.

APPENDIX 1 - SPECIFICATION GUIDE FOR AIRPORT FIBER OPTIC CABLES

The following requirements and characteristics should be considered when specifying optical cables procured for use in airport areas (e.g., runway loops).

a. Cables should be suitable for use in harsh environments and outdoor applications; the cables may be exposed to jet fuels, oils and other harsh chemicals.

b. The individual aramid yarns of distribution style cable should be precisely tensioned to ensure low transmission loss when the cable is under tension and operating over a wide temperature range. Precise tensioning also increases the breaking strength of the cable.

c. The operating temperature range of the cable should be at least -40 degrees C to +85 degrees C.

d. Cables should be impervious to fungus, sunlight/ultraviolet radiation, moisture and humidity.

e. Vendors should provide cable samples and drawings.

APPENDIX 2 - TYPICAL FIBER SPECIFICATIONS

MULTIMODE

SIZE	850 nm		1300 nm	
µm	dB/km	MHz-km	dB/km	MHz-km
50/125	4.0	400	2.0	400
50/125	3.0	400	1.0	400
50/125	3.0	600	1.0	600
50/125	3.0	400	1.0	1000
50/125	3.0	800	1.0	800
62.5/125	5.0	100	3.0	100
62.5/125	4.0	160	2.0	300
62.5/125	4.0	160	2.0	500
62.5/125	4.0	400	2.0	400
62.5/125	3.0	160	1.0	500
62.5/125	3.0	200	1.0	600
62.5/125	3.0	400	1.0	600
200PCS	10.0	20		

SINGLE-MODE

SIZE	1300 nm	1550 nm
µm	dB/km	dB/km
8.7/125	0.5	0.5
8.7/125	1.0	---
8.7/125	1.0	1.0

PLASTIC

SIZE µm	650 nm dB/km
1000	200

RANGE OF AVAILABLE OPTICAL PERFORMANCE

	ATTENUATION (dB/km)		BANDWIDTH (MHz-km)	
WAVELENGTH	850 nm	1300 nm	850 nm	1300 nm
FIBER TYPE				
50/125	2.5-4.0	0.6-1.5	400-1000	400-2000
62.5/125	3.0-5.0	0.8-2.0	100-800	200-1400

APPENDIX 3 - ACRONYMS, ABBREVIATIONS AND DEFINITIONS

ACRONYMS AND ABBREVIATIONS

The following is a list of acronyms and abbreviations applicable to this handbook.

AAL	ATM Adaption Layer
ALS	Approach Lighting System
ANSI	American National Standards Institute
ANTC	Advanced Network Test Center
APD	Avalanche Photodiode
ASDE	Airport Surface Detection Equipment
ASR	Airport Surveillance Radar
ATCT	Airport Traffic Control Tower
ATM	Asynchronous Transfer Mode
Bellcore	Bell Communications Research
B-ISDN	Broadband-ISDN
CCITT	International Telegraph and Telephone Consultative Committee (refer to ITU-T)
COTS	Commercial Off-the-Shelf
CRC	Cyclic Redundancy Check
CSMA/CD	Carrier Sense Multiple Access with Collision Detection
DBRITE	Digital Bright Radar Indicator Tower Equipment

DQDB	Distributed Queue Dual Bus
EIA	Electronic Industries Association
FAA	Federal Aviation Administration
FDDI	Fiber Distributed Data Interface
FDMA	Frequency Division Multiple Access
FOCSM	Fiber Optic Communications System Multiplexer
FOMAU	Fiber Optic Medium Attachment Unit (ANSI/IEEE 802.3)
GS	Glide Slope
GOSIP	Government Open Systems Interconnection Profile
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output
IOC	Integrated Optical Circuit
IOL	Interoperability Lab
ILD	Injection Laser Diode
ISDN	Integrated Services Digital Network
ISO	International Standards Organization
ITU-T	International Telecommunication Union-Telecommunication Standards Sector
LAN	Local Area Network
LED	Light-Emitting Diode
LLC	Logical Link Control
MAC	Medium Access Control

MALSR	Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights
MAN	Metropolitan Area Network
MLS	Microwave Landing System
NAILS	National Airspace Integrated Logistic Support
NAS	National Airspace System
NBS	See NIST
NDI	Non-developmental Item
NEC	National Electric Code
NIST	National Institute of Standards and Technology (formerly National Bureau of Standards, NBS)
NNI	Network Node Interface
OSI	Open System Interconnection
PAPI	Precision Approach Path Indicator
PHY	Physical Layer Protocol
PIN	Positive-Intrinsic-Negative
PLC	Programmable Logic Controller
PMD	Physical Layer Medium Dependent
POF	Plastic Optical Fiber
RAIL	Runway Alignment Indicator Lights
RFI	Request for Information
RFP	Request for Proposal

ROM	Read-only Memory
RT	Radio Transfer
RVR	Runway Visual Range
RX	Receiver
SMAP	System Management Application Process
SMT	Station Management
SONET	Synchronous Optical Network
STP	Shielded Twisted Pair
TIA	Telecommunications Industries Association
TML	Television Microwave Link
TRACON	Terminal Approach Control Tower
TX	Transmitter
UL	Underwriters Laboratory
UNI	User Network Interface
UTP	Unshielded Twisted Pair
VCC	Virtual Channel Connection
WAN	Wide Area Network
XCVR	Transceiver

DEFINITIONS

Complete fiber optic technology glossaries and technology tutorials are provided in many sources, including DOT/FAA/CT-TN91/9 (Glossary of Optical Communications Terms), Order 6000.15 (General Maintenance Handbook for Airway Facilities), IEEE STD 812 (Glossary of Terms, Fiber Optics), Order 6650.8 (Airport Fiber Optic Design Guidelines), FED-STD-1037B (revised edition expected November 1995) (Telecommunications: Glossary of Telecommunication Terms) and EIA-440 (Fiber Optic Terminology). Definitions of fiber optic terms pertinent to this document are provided below.

asynchronous transmission Digital data transmission in which the start of transmission of each character, or block of characters, is arbitrary with respect to time. *Note:* The time intervals between characters or blocks of characters are also arbitrary.

asynchronous transfer mode (ATM) A method of digital data transfer in which all types of information (data, voice and video) are passed in high-speed cells of fixed size over a virtual circuit that is established on demand.

commercial off-the-shelf (product) An item or equipment that can be purchased through a commercial retail or wholesale distributor at prices based on established catalog or market prices.
fiber optic connector A demountable device used to connect an optical fiber to an optical transmitter or receiver or to another optical fiber.

laser *Acronym for* light amplification by stimulated emission of radiation. Any of a class of optoelectronic devices that produce an intense, coherent, directional beam of optical radiation by stimulating electronic, ionic, or molecular transitions to higher energy levels so that when they return to lower energy levels, they emit photons consistent with the differences in the energy levels involved. *Note:* The active medium of a laser is usually a solid or a gas. Solid-state lasers (injection laser diodes or, simply, laser diodes) may be used as optical sources in communications transmitters.

loose-buffered cable Cable that contains fibers that are not in intimate contact with the cable structure and are therefore isolated from axial and transverse forces of small magnitude applied to the cable.

multimode fiber Optical fiber having a relatively large core cross-section capable of transmitting light via more than one mode of propagation (i.e., having more than one solution to Maxwell's equations). *Note 1:* Multimode fibers may use a conventional LED source, but require regeneration at shorter intervals than single-mode fibers due to modal distortion. *Note 2:* In general, multimode fibers have a higher attenuation coefficient than single-mode fiber.

multiport repeater An active digital electronic or optoelectronic repeater having a large number of optical I/O ports (usually a minimum of four) in which an input to any port appears at the output of all ports. *Note:* The optical multiport repeater may also perform such functions as signal retiming and regeneration before presenting the signal to the outputs.

non-developmental item (NDI) A product or device that may be produced without further development or refinement of the product or the production process. *Note:* NDI may or may not be a commercial off-the-shelf (COTS) item.

optical fiber Any filament of dielectric material that guides light.

passive star A star configuration that behaves like a bus configuration; *i.e.*, transmissions from any device in the network are received by all devices in the network, including the transmitting device. *Note:* The number of devices that may comprise the passive star network and the distances between the passive star coupler and the network devices is dependent on the combined attenuation of optical connectors and optical cable as well as the number of ports at the coupler.

proof test Of optical fibers, a tensile load test, applied as part of the manufacturing process, to test for the presence of significant mechanical flaws in the finished fiber, prior to cabling.

ring or loop topology A closed path transmission system in which all nodes are connected serially. *Note:* Redundancy is provided in the ring configuration by the capability for data to travel in either direction along the ring.

single-mode fiber Optical fiber having a relatively small core cross-section that allows the transmission of light via only one mode of propagation (*i.e.*, only one solution to Maxwell's equations). *Note 1:* Single-mode fiber typically requires regeneration every 30 miles. *Note 2:* Single-mode fiber cannot be used with conventional LED optical sources; sources with minimum beam divergence must be used.

synchronous transmission Data transmission in which the start of transmission of each character or block of characters is related to a specific instant in time. *Note:* Timing is provided by a clock, which applies a timing bit or pulse to the digital data stream or analog signal, respectively.

tight-buffered cable An optical cable that contains one or more fibers that are in direct contact with the cable structure, but are cushioned from transverse and axial loads applied to the cable.

token ring network A closed loop serial interconnection, comprising three or more communicating entities, in which supervisory control is accomplished by circulating a distinctive pattern (group) of bits, called a "token." *Note:* When there is no traffic on the network, the token is passed.

sequentially to all members of the network; whenever a member desires control of the network, it seizes the token, removing it from circulation, and transmits data; when the transmission is complete, the token is returned to circulation.